Accelerated Innovation Management (AIM)

- WATER MANAGEMENT + EFFICIENCY
- SUSTAINABLE WATER RESOURCES
- 22ND CENTURY AGRONOMICS
- AIR QUALITY
Accelerated Innovation Management (AIM)

- Water Management + Efficiency
- Sustainable Water Resources
- 22nd Century Agronomics
- Air Quality
Speakers

Gabriele Ludwig, Almond Board (Moderator)

Graham Fogg, University of California, Davis
Understanding Groundwater: The Hidden Resource

Graham E. Fogg
The Almond Conference
Sacramento, California
December 9, 2015
Outline

• Groundwater fundamentals
  – California groundwater occurrence & general background
  – Climate change and a new epoch of scarcity
  – Overdraft & negative consequences
    • Non-sustainable storage depletion
    • Subsidence
    • Surface water & ecosystem effects
    • Increased energy costs
    • Bad water intrusion from aquitards and from depth
    • Basin salt imbalance
    • Seawater intrusion
  – Sustainable yield

• Groundwater myths
  – Pumping of “fossil water” is non-sustainable
  – Groundwater storage depletion always takes a long time to recover
  – Groundwater levels tell us how much groundwater storage is changing
  – Quality of most groundwater is degraded
  – Good quality groundwater today is likely to stay that way
  – Potential myth: climate change will decrease groundwater recharge
California Water System

http://www.water.ca.gov/maps/allprojects.html
Snow Water Storage

**Definition:** Snow-Water Equivalent (SWE) is a common snowpack measurement. It measure the volume of water contained within the snowpack (as a measure of depth).

**Figure:** Mote (2006) Fig 5a: Observed changes in 1 April Snow-Water Equivalent over the 1960 to 2002 period of record from snow course observations.
The CA Water Quantity Problem

- 8th largest economy in the world.
- Produces 50% of nation’s fruits & vegetables with irrigation.
- Depends on snow-storage and historically well-timed snow-melt to satisfy demand.
- This system cannot function properly as the snow pack diminishes due to warming.
The Major Stores of Water:

1. Snow
2. Mountain Groundwater
3. Surface Reservoirs
4. Alluvial Valley Groundwater (Especially Central Valley)
Available Central Valley Groundwater Storage Volume

- 10 to $50 \times 10^6$ ac-ft

- CA’s 4 largest reservoirs = $13 \times 10^6$ ac-ft
  (Shasta, Oroville, Trinity, New Melones)
Two Bank Accounts

When Account A is depleted, uncontrolled withdrawals from Account B occur.
The Major Stores of Water:

- Snow
- Mountain Groundwater
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- Alluvial Valley Groundwater (Especially Central Valley)
Groundwater and Surface Water

From CA Water Plan 2014
We apply three perspectives to every project.

INFORMATION

Connected water resources science & management

INSTITUTIONS

INFRASTRUCTURE

Current program foci:
- Headwater Management
- Groundwater Management
- Water-Energy Nexus
- Intelligent Water System
Integrating water-resources data & information systems

- Existing data
- Sensor networks
- Well monitoring
- Aircraft
- Satellite
- Market, demand & energy data
- QA/QC
- User interfaces
- Core data
- Point data, time series
- Interpolated & blended spatial data
- Value-added
- Modeled data
- Groundwater aquifer water balance
- Basin-scale water balance
- Modeling & prediction
- Decision support
- Water decision making
- Value-added
- Market, demand & energy data
- Policy & legal data & constraints: water rights, diversions, ecosystems

UC Water Security and Sustainability Research Initiative
http://ucwater.org/
Aug 31, 2015
During fallow or dormant periods, agricultural lands have the potential to serve as percolation basins for groundwater recharge.

http://california.oregonstate.edu

April-June 2015
Sutter Bypass, Sutter Co., 1997 flood
Climate Change and Groundwater: Higher Flooding Risks BUT Greater Recharge??

1997, 1995 Flood Events
Sacramento County, CA

Flooding and Groundwater Levels

<table>
<thead>
<tr>
<th>Groundwater Level (ft above sea)</th>
<th>Streamflow @ MHB (CFS)</th>
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<tbody>
<tr>
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Laura Chun/The Sacramento Bee
--------------- VERSUS: --------------------------

Floodplain w/ set-back levees:

http://remote.ucdavis.edu
Groundwater Occurrence
Major Aquifers (http://nationalatlas.gov/natlas/natlasstart.asp)
San Joaquin Valley Groundwater (from Faunt, 2009)

Pre-Development

Post-Development
MIXED- AND SUSPENDED-LOAD CHANNEL SYSTEM
CALVERT BLUFF FORMATION
FACIES ARCHITECTURE

Suspended-load channel

Galloway & Hobday 1983

Bureau of Economic Geology

QA-2480
Groundwater

- Saturated zone
- Unsaturated zone
- Water table
- Ground water
- Land surface
- Surface water
- Creviced rock
- Groundwater
  - Water (not ground water) held by molecular attraction
  - Surrounds surfaces of rock particles
- Gravel
  - Air

Approximate level of the water table
All openings below water table full of ground water
Myth: Old (1,000’s of yrs) groundwater is fossil water that is not replenished enough to support pumping.
Groundwater Overdraft: Pumping more groundwater than the system can sustain

**Potential consequences:**

- Non-sustainable storage depletion
- Subsidence
- Surface water & ecosystem effects
- Increased energy costs
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- Seawater intrusion
Groundwater Overdraft Trends, Central Valley

The USGS Groundwater Resources Program funded this study, one of 30 regional aquifer studies the USGS is conducting to assess the Nation’s groundwater availability. Intense competition for groundwater resources in California was an important factor in choosing the Central Valley as one of the first studies undertaken and completed.
Groundwater Overdraft: Pumping more groundwater than the system can sustain

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Approximate location of maximum subsidence in the United States identified by Joe Poland (pictured)
Figure TL-23 Depth to Groundwater Hydrograph and Vertical Land Surface Displacement at UNAVCO GPS Site 304, near the City of Madera

Source: USGS 2011 presentation on Central Valley subsidence. Land surface elevation data from UNAVCO Station 304; depth to water data provided by Luhdorff and Scalmanni Consulting Engineers.
Subsidence Induced Canal Damage

From http://www.rcac.org/pages/7147/1002
Groundwater Overdraft: Pumping more groundwater than the system can sustain

**Potential consequences:**

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- **Surface water & ecosystem effects**
- Increased energy costs
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Figure 13. Effects of pumping from a hypothetical ground-water system that discharges to a stream. (Modified from Heath, 1983.)
From Faunt (2009)
Groundwater Overdraft: Pumping more groundwater than the system can sustain

Potential consequences:

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Potential for Water Quality Degradation from Below is Clear and Present, but Unaddressed

Figure 98. The thickness of the Central Valley aquifer system that is saturated with freshwater is greatest in the San Joaquin Valley, where freshwater extends to a depth of more than 4,000 feet below land surface.

EXPLANATION

Thickness of aquifer saturated with fresh ground water, in feet

- 500
- 1,500
- 2,500
- 3,500

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Line of equal thickness of aquifer saturated with fresh ground water—Interval 500 feet

Woodland Area Aquifer System Network (Stephen Maples, HYD 273)
Groundwater Overdraft: Pumping more groundwater than the system can sustain

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The danger of a hydrologic basin losing its outlet....
San Joaquin Valley Groundwater (from Faunt, 2009)

**Pre-Development**

**Post-Development**
Mono Lake: Closed Basin
Groundwater Overdraft: Pumping more groundwater than the system can sustain

Potential consequences:

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Salt Water Intrusion
Groundwater Quality is Degrading in Many Systems, But Most of the Groundwater Quality is Still Good
Age Distribution & Sustainability: Groundwater Ages are Highly Mixed!
Historic Nitrate Trends, TLB: Exceedance Rate

- Percent of wells above natural background
- Number of wells tested
- Percent of wells above half nitrate MCL
- Percent of wells above nitrate MCL

Year:
- 1945
- 1955
- 1965
- 1975
- 1985
- 1995
- 2005
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